Autonomous Ocean Sampling Network II: Assessing the Large Scale Hydrography of the Central California Coast

Dr. Margaret Anne McManus
University of California Santa Cruz
Ocean Sciences Department
Santa Cruz, CA 95064
phone: (831) 459-4632 fax: (831) 459-4882 email: margaret@es.ucsc.edu

Dr. Francisco Chavez
Monterey Bay Aquarium Research Institution
7700 Sandholt Road
Moss Landing, CA 95039
phone: (831) 775-1709 fax: (831) 775-1645 email: chfr@mbari.org

Grant Number: N000140310267
http://www.mbari.org/aosn/

LONG-TERM GOAL

The goal of the Autonomous Ocean Sampling Network II (AOSN II) project is to assimilate near real-time data (from shipboard surveys, Autonomous Underwater Vehicles (AUVs), gliders, aircraft and moorings) into advanced ocean models to improve our ability to observe and predict the ocean.

OBJECTIVES

In August and September of 2003, the AOSN II field experiment focused on the integration of many different observational platforms and two different modeling systems in Monterey Bay and adjacent waters. Our three hydrographic surveys are one component of AOSN II. Our large-scale hydrographic data was used for data assimilation and model validation and to provide a regional context for smaller scale work in Monterey Bay. The objectives of our study are: (1) To determine how the Inshore Countercurrent and the California Undercurrent interact with coastal circulation in the Monterey Bay region, (2) to determine how this interaction affects the temporal and spatial evolution of upwelling features, and (3) to identify the temporal and spatial responses of the marine ecosystem to upwelling features.

APPROACH

Hydrographic Surveys: We conducted three hydrographic surveys (2–6 August, 21–25 August, 3–6 September 2003). In each survey, forty-nine hydrographic stations at 10 or 20 km intervals were occupied along 5 cross-shore (~80 km) transects and 1 alongshore (~100 km) transect (Figure 1). On each survey, currents were measured to 467 m in depth, with a 150 kHz shipboard acoustic Doppler current profiler (ADCP). Water-column profiles, as well as water samples, were obtained at 49 stations to a maximum depth of 1000 m. In addition, underway surface data were also recorded. The ADCP data include north/south (v) and east/west (u) currents. Water-column profiles include measurements of temperature, salinity, fluorescence, oxygen, and photosynthetically available

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Autonomous Ocean Sampling Network II: Assessing the Large Scale Hydrography of the Central California Coast**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of California Santa Cruz,,Ocean Sciences Department,,Santa Cruz,,CA,95064**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long-term goal is to advance our understanding of the ecology of bioluminescent organisms and the mechanisms governing the temporal and spatial variability of bioluminescence in the coastal ocean. With improvements in technology, finer-scale resolution and concurrent physical, chemical and biological data over relevant scales will enable better predictability of bioluminescence events in the nearshore coastal ocean.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

radiation (PAR). Underway surface data include winds, PAR, as well as temperature, salinity, and fluorescence at 3 m depth. The hydrographic surveys were carried out by Dr. Margaret McManus, Dr. Shaun Johnston (UCSC postdoctoral researcher), and Ms. Olivia Cheriton (UCSC graduate student).

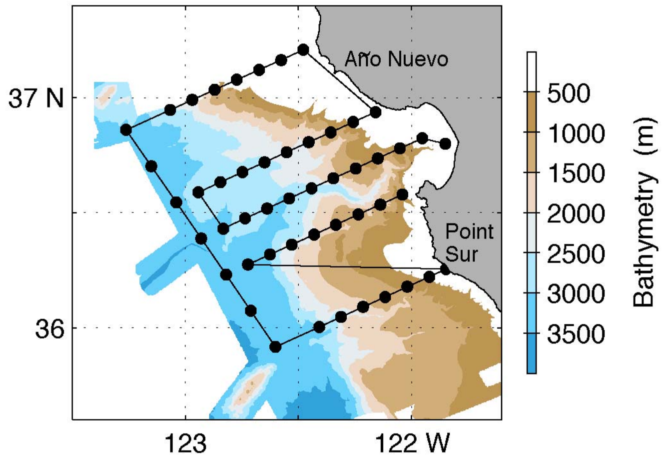

Figure 1. A total of 49 hydrographic survey stations are shown along 5 cross-shore transects and 1 alongshore transect in Monterey Bay and adjacent waters.

Data Handling/Availability: All data from the ADCP, profiling package, and underway data acquisition system were processed in real-time aboard the RV Point Sur with programs developed for this project. ADCP data were controlled for quality and entered into a Common Oceanographic Data Access System (CODAS) database. Data were converted to NetCDF format and transmitted to the AOSN control room each day by ftp, via a TrackNet Internet connection. These datasets are being used by the modeling group for data assimilation and model validation. These data are also available at http://polarbear.shore.mbari.org/AOSNII.

Water Samples: Nutrients, Pigments, and Trace Metals: Niskin bottle samples were obtained from the surface to a maximum depth of 1000 m during each cast. Ms. Anna Pfeiffer-Hoyt (UCSC graduate student) assayed these seawater samples for nutrients (NO_3+NO_2, PO_4, SiO_4) and chlorophyll *a* and other pigments (see Pennington and Chavez 2000). Personnel involved in water sample collection include 3 MBARI technicians (Ms. Anne Hess, Dr. Tim Pennington, and Mr. Erich Reinecker), 1 MBARI postdoctoral researcher (Dr. Victor Kuwahara), 2 UCSC graduate students (Ms. Olivia Cheriton, Ms. Anna Pfeiffer-Hoyt), 1 Duke University graduate student (Ms. Veronica Lance) and 5 undergraduate students or recent graduates (Mr. Nilo Alvarado, Ms. Marguerite Blum, Ms. Robyn Matteson, Mr. Paul Myer, and Mr. Ben Perlman). Water samples were also analyzed for trace metals by MBARI technicians (Dr. Ginger Elrod and Mr. Josh Plant).

WORK COMPLETED

On our 3 surveys, ADCP and underway data were recorded continuously. Profiles were obtained at 49 stations with water samples at 0, 5, 10, 20, 40, 60, 80, 100, 150, 200, 500, and 1000 m. Twelve of the 49 stations had a second profile with higher resolution water sampling at 0, 5, 10, 20, 30, 40, 60, 80, 100, 150, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 m. ADCP data were controlled for quality and entered into a Common Oceanographic Data Access System (CODAS) database. ADCP, CTD,

and underway data were converted to NetCDF format and transmitted to the AOSN control room each day by ftp, via a TrackNet Internet connection.

RESULTS

Preliminary results from our cruises are presented below.

Upwelling/Relaxation Conditions: Our three cruises took place during periods of either relaxation from upwelling, or exceptionally weak upwelling. For the most part, winds were weakly southeastward, except at the mouth of Monterey Bay where northwestward winds were measured on all 3 cruises. Wind measurements aboard the RV Point Sur are made at 20 m above sea level. Prior to cruise 1 and between cruises 1 and 2, upwelling favorable conditions existed for 1-2 weeks. Cruise 3 took place after several days of weak winds (~2-3 m s^{-1}), these conditions continued for most of the cruise. Sea surface temperatures of 14^{o}C and salinities of 33.4 were measured near the upwelling centers at Año Nuevo and Point Sur, but due to the persistent relaxation conditions these conditions were 5^{o}C warmer and 0.4 less salty than typically observed during August and September (Rosenfeld et al. 1994) (Figure 2).

Physical-Biological Interactions: These periods of exceptionally weak winds and strong insolation (PAR > 2 Ein m^{-2} s^{-1}) led to mixed layer depths of <20 m and permitted the formation of small density steps (on the order of 5 meters). Strong subsurface peaks in fluorescence (up to 30 mg m^{-3}) were commonly associated with these density steps. These subsurface peaks were often seen in layers less than 5 m thick and can accurately be classified as thin layers (Figure 3b) (Dekshenieks et al. 2001, McManus et al. in press). On all 3 cruises, these fluorescence peaks varied in thickness and followed the 1025 kg m^{-3} isopycnal ***for distances up to 100 km***. Fluorescence maxima at the surface and near the coast appeared to move offshore and subduct beneath surface water (Figure 3a).

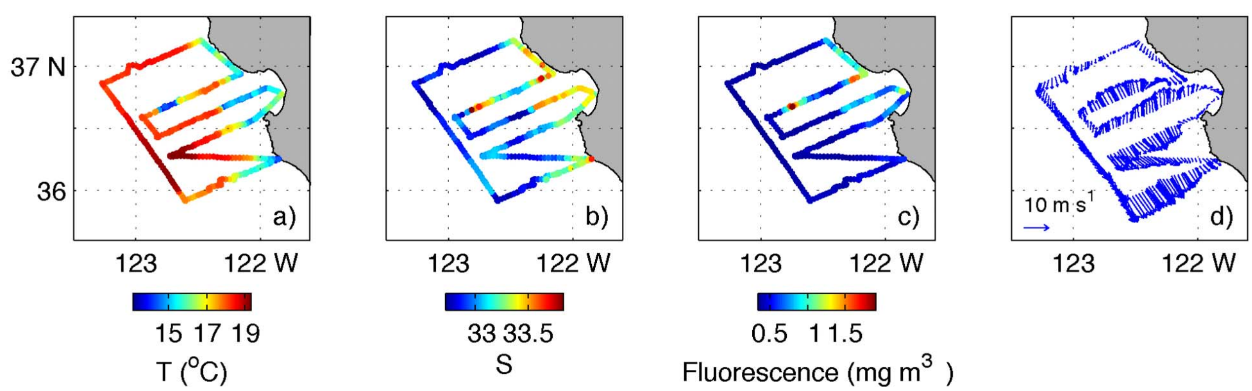

Figure 2. Underway data from cruise 2 shows northwestward winds or weakly upwelling favorable southeastward winds and relatively high temperatures and low salinities at the coastal upwelling centers.

Several cyclonic and anticyclonic eddies were sampled during these cruises leading to upwelling and downwelling of the 1025 kg m^{-3} isopycnal and the associated fluorescence maximum (Figure 3). From these cruise results ***we hypothesize that compressing and stretching of isopycnals in eddies may be***

one process for producing thin layers of fluorescence and later thickening them, however additional research and analysis will be needed.

Currents: Typically, the core of the California Undercurrent transports warm, high salinity water poleward; reaches maximum speeds of 0.2-0.5 m s^{-1}; and is continuous alongshore over hundreds of kilometers at 100-300 m depth, 20-25 km off the shelf break (Collins et al. 2000, Pierce et al. 2000, Noble and Ramp 2000). The inshore countercurrent appears in fall and winter transporting surface-waters northward (Collins et al. 2000). The relatively calm sea state during our cruises allowed for ADCP measurements from 19-467 m. During cruises 1 and 2, poleward flow reached 0.2-0.4 m s^{-1}, occupied the entire water column covered by the ADCP, and extended 60-90 km away from the shelf. Distinguishing the Inshore Countercurrent from the California Undercurrent by current speed is not possible, but spiciness suggests the California Undercurrent reached 50 m. During cruise 3, the undercurrent was the weakest with speeds <0.2 m s^{-1}.

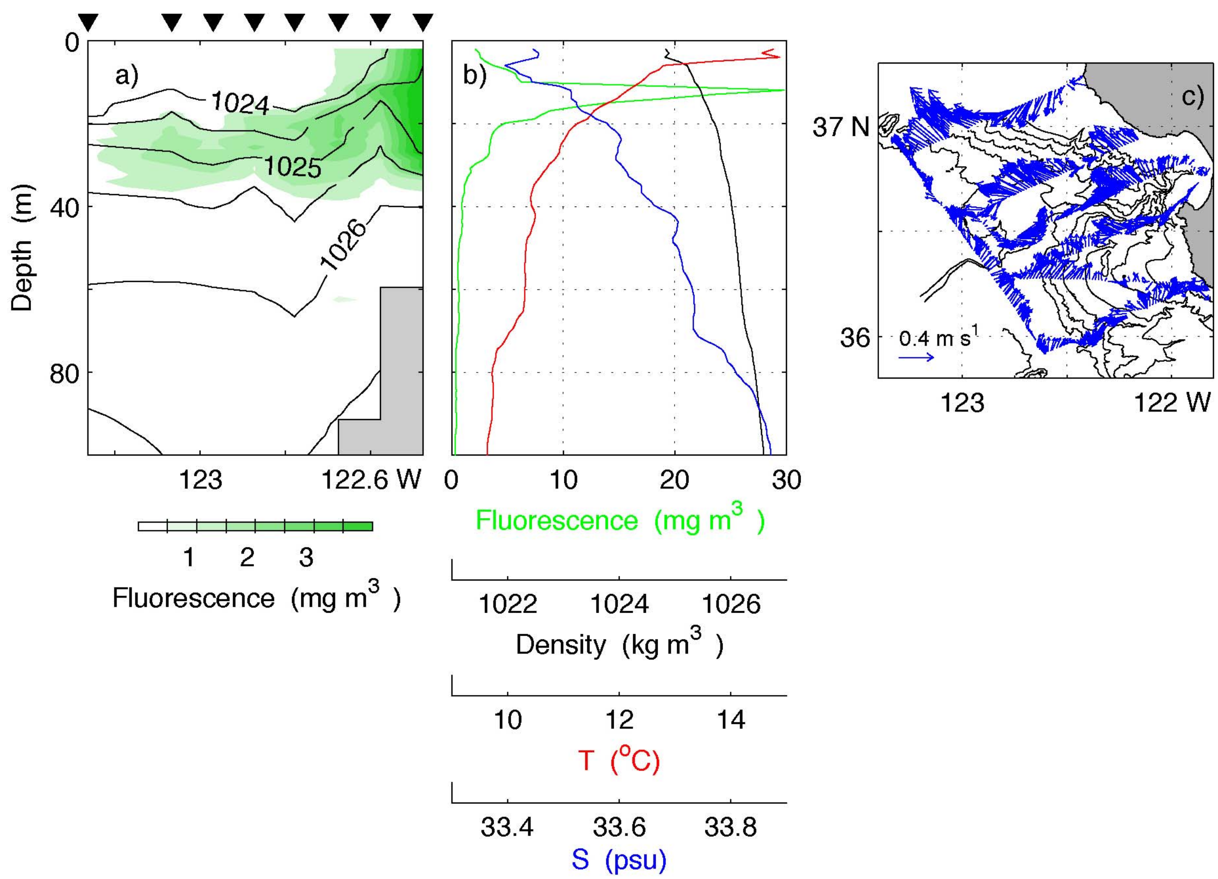

Figure 3. a) During cruise 2 subduction of the fluorescence maximum along the 1025 kg m^{-3} isopycnal beneath an eddy on the northern cross-shore transect. Triangles indicate the location of CTD casts. b) A strong subsurface fluorescence maximum is associated with steps in the salinity profile at station 3 on the middle transect. c) Poleward flow at 19 m is found and an eddy is located at the northernmost transect. Bathymetry contours are at 500 m intervals.

During cruise 1, saline water from Año Nuevo flowed southward near the coast as far as Monterey Bay as expected in upwelling conditions (Rosenfeld et al. 1994). On cruise 2 and 3, this flow did not penetrate as far south. On all cruises, weak onshore flow was typically seen throughout the water column along the offshore transect and at least one eddy was present in the upper 75 m (Figure 3c).

Work in Progress: We are completing analysis of our cruise data and have two manuscripts in preparation. We are examining the role of eddies in stretching and compressing isopycnals and their influence on the amplitude, thickness, and depth of sub-surface, thin layer structures. We are also considering other physical parameters, such as stratification, current shear, Richardson number, and wind mixing. We plan to use potential vorticity as an additional tracer of subsurface flow. Further comparison of ADCP currents with geostrophic currents referenced to a 1000-m level of no motion will also be made.

IMPACT/APPLICATIONS

AOSN II will advance the present state of predictive three-dimensional physical-biological modeling. Predicting the physical hydrography and biological dynamics in the nearshore environment is critical for mitigating spills of hazardous material, understanding the marine ecosystem, and national security. In addition, data collected during the hydrographic surveys will be valuable for investigating thin layer formation, distribution, and broadening in offshore waters. Finally, data collected on all 3 cruises will be used in a high-resolution climatology of California coastal waters by Dr. Avijit Gangopadhyay (University of Massachusetts, Dartmouth).

RELATED PROJECTS

(1) Autonomous Ocean Sampling Network II (AOSN II): System Engineering and Project Coordination. Bellingham, Chandler #N00014-02-1-0856.

(2) Monterey Bay Sampling. Bishop #N00014-03-WX20009.

(3) Coastal Bioluminescence: Measurement and Prediction. Case #N00014-97-1-0424.

(4) Development of a Monterey Bay Forecasting System Using the Regional Ocean Modeling System (ROMS). Chao #N00014-03-1-0208.

(5) Deep Autonomous Gliders for the "Autonomous Ocean Sampling Network II' Experiment. Davis, Sherman #N00014-03-1-1049.

(6) An Autonomous Glider Network for the Monterey Bay Predictive Skill Experiment/AOSN-II. Fratantoni #N00014-02-10846

(7) Instrumentation in support of autonomous glider operations. Fratantoni #N00014-03-1-0736.

(8) Glider communication and sensor enhancements in support of AOSN. Fratantoni #N00014-02-1-0846.

(9) Implementing FORMS (Feature Oriented Regional Modeling System) for the Monterey Bay forecasting system using HOPS and ROMS. Gangopadhyay #N00014-1-0206.

(10) High-Resolution Measurement of Coastal Bioluminescence: II. Improving short-term predictability across seasons. Haddock #N00014-00-1-0842.

(11) Participation in AOSN II. Healey #N00014-03-WR20063.

(12) Underwater Glider Dynamics and Control. Leonard #N00014-02-1-0861.

(13) Underwater Glider Networks and Adaptive Ocean Sampling. **Leonard**, Rowley, Marsden #N00014-02-10826.

(14) Adaptive sampling during AOSN-II. **Majumdar** #N00014-03-1-0559.

(15) Quantification of Littoral Bioluminescence Structure and Induced Water Leaving Radiance. **Moline** #N00014-03-1-034.

(16) Aerial Surveys of the Atmosphere and Ocean off Central California. **Ramp**, Paudan, Nuss, and Collins #N0001403WR20002, #N0001403WR20006.

(17) Hyperspectral Radiometer for Airborne Deployment. **Ramp** #N0001403WR20209.

(18) Development of a Regional Coastal and Open Ocean Forecast System: Harvard Ocean Prediction System (HOPS). **Robinson** #N00014-97-1-0239.

(19) Use of a Circulation Model to Enhance Predictability of Bioluminescence in the Coastal Ocean. **Shulman** #N00014-03-WX-20882, #N00014-03-WX-20819. Rosenfeld, Paduan #N00014-03-WR-20009. McGillicuddy #N00014-02-10853.

REFERENCES

Collins CA, N Garfield, TA Rago, FW Rischmiller, and E Carter, 2000, Mean structure of the inshore countercurrent and California undercurrent off Point Sur, California, Deep-Sea Res. II, 47, 765-782.

Dekshenieks MM, PL Donaghay, JM Sullivan, JEB Rines, TR Osborn and MS Twardowski, 2001, Temporal and spatial occurrence of thin phytoplankton layers in relation to physical processes, Mar. Ecol. Prog. Ser., 223, 61-71.

McManus MA, AL Alldredge, A Barnard, E Boss, J Case, TJ Cowles, PL Donaghay, L Eisner, DJ Gifford, CF Greenlaw, C Herren, DV Holliday, D Johnson, S MacIntyre, D McGehee, TR Osborn, MJ Perry, R Pieper, JEB Rines, DC Smith, JM Sullivan, MK Talbot, MS Twardowski, A Weidemann and JRV Zaneveld, in press, Changes in characteristics, distribution and persistence of thin layers over a 48-hour period, Mar. Ecol. Prog. Ser.

Noble MA, and SR Ramp, 2000, Subtidal currents over the central California slope: evidence for offshore veering of the undercurrent and for direct, wind-driven slope currents, Deep-Sea Res. II, 47, 871-906.

Pierce S.D, RL Smith, PM Kosro, JA Barth and CD Wilson, Continuity of the poleward undercurrent along the eastern boundary of the mid-latitude north Pacific, Deep-Sea Res. II, 47, 811-829.

Pennington JT and FP Chavez, 2000, Seasonal fluctuations of temperature, salinity, nitrate, chlorophyll and primary production at station H3/M1 over 1989-1996 in Monterey Bay, California, Deep-Sea Res. II, 47, 947-973.

Rosenfeld LK, FB Schwing, N Garfield, DE Tracy, 1994, Bifurcated flow from an upwelling center: a cold water source for Monterey Bay, Cont. Shelf Res., 14, 931-964.